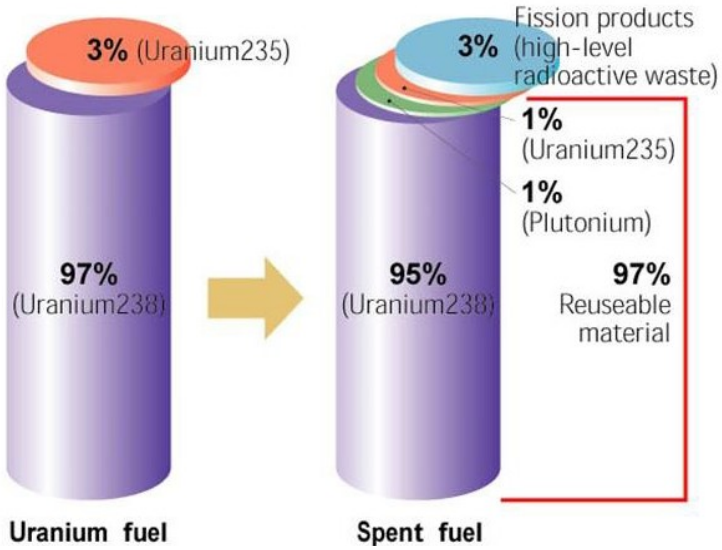
The Facts About Used Nuclear Fuel

The anti-nuclear mantra is that there is no solution to the “problem” of used nuclear fuel, and for this reason nuclear power plants should be shut down. The truth of the matter is that there is no solution only for the “political problem” of used nuclear fuel, because scientifically and practically speaking, there is no problem.

The question of what to do with used nuclear fuel was answered decades ago. It’s called reprocessing, and it was U.S. scientists who developed the reprocessing technology that is being used by other countries in the world today. The insurmountable political problem to reprocessing use nuclear fuel in the U.S., known as nuclear proliferation, is the false assumption that reprocessing used nuclear fuel produces plutonium that can be used to manufacture nuclear weapons.

We will begin this discussion by first comparing new and used nuclear fuel to see what the constituents of used fuel actually are. The graphic below illustrates the content of new and used nuclear fuel.



[Source: Japan Nuclear; https://www.fepc.or.jp/english/library/power_line/detail/14/]

The cylinder on the left represents 3% enriched new reactor fuel (i.e., natural uranium enriched to 3% in the U-235 isotope). The cylinder on the right represents nuclear reactor fuel that has been in a reactor core producing power for about 4 years. 97% of used nuclear fuel consists of reusable material (U-235, U-238, and plutonium), while only 3% is actually waste. Reprocessing of used nuclear fuel would result in usable uranium and

plutonium for nuclear reactors, and numerous radionuclides that could be used in medical and industrial applications, as shown in the table below.

Used Fuel Material	Material Disposition
Reprocessed plutonium and uranium	Fission in thermal, fast, or sub-critical reactors
Fuel cladding, filters	Less stringent storage as intermediate-level waste
Long-lived fission and activation products	Nuclear transmutation or geological repository
Medium-lived fission products Cs-137 and Sr-90	Medium-term storage as high-level waste
Useful radionuclides and noble metals	Industrial and medical uses

High level waste from used reactor fuel consists of two distinct components – fission products and actinide element isotopes. The actinide isotopes, primarily plutonium, neptunium, americium, and curium, are the activation products created by non-fission capture of neutrons by U-238. Using accelerators to transmute the long-lived fission products and actinides would reduce the radioactivity of this waste.

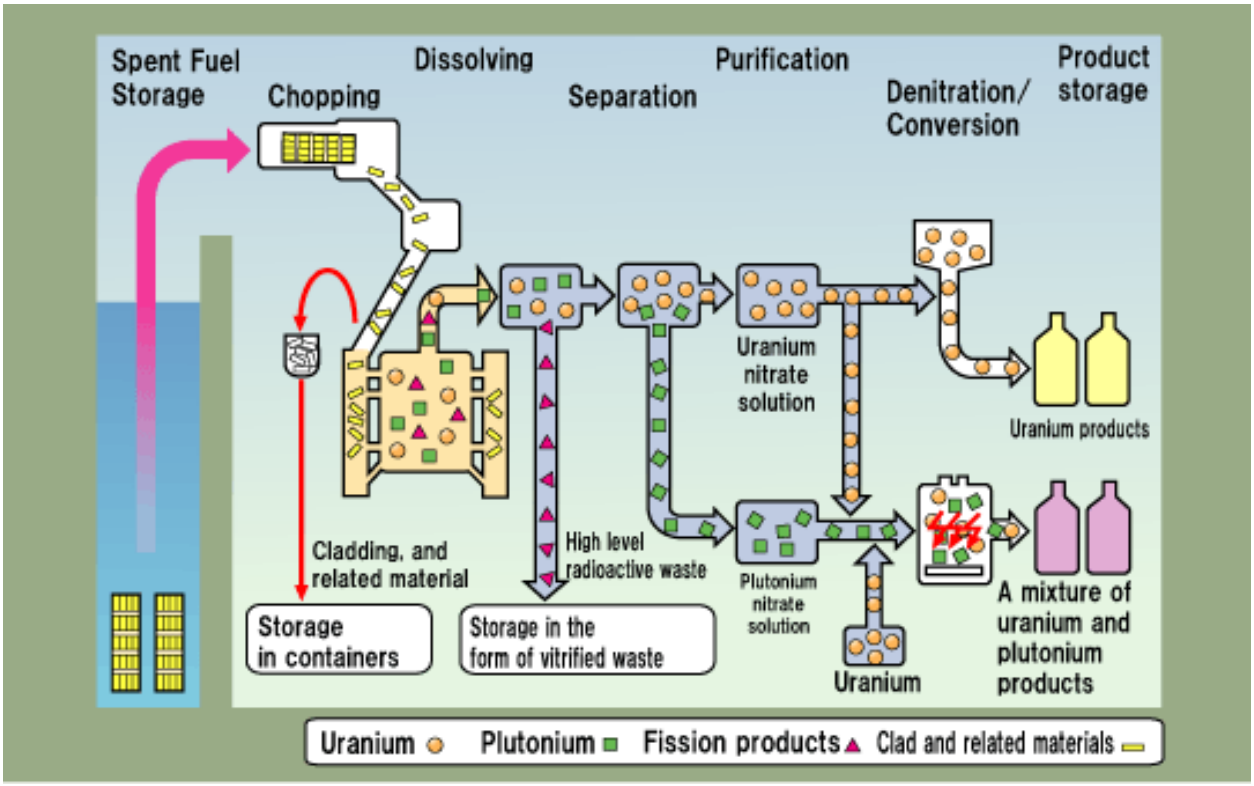
Used nuclear fuel waste can be characterized by both volume and radioactivity content as shown in the following table.

	By Volume	By Radioactive Content
High Level Waste	3%	95%
Intermediate Level Waste	7%	4%
Low Level Waste	90%	1%

High level waste accounts for only 3% of the total waste volume, but 95% of the radioactivity content, while low level waste accounts for 90% of the total waste volume, but only 1% of the radioactivity content. It is very apparent that used nuclear fuel should be reprocessed to minimize the amount of highly radioactive material that must be carefully managed.

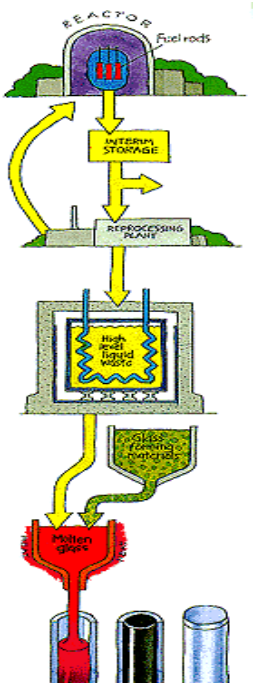
Reprocessing removes certain fission products and shorter-lived actinide isotopes from used fuel so the remaining used fuel can be manufactured into new fuel for advanced reactors. Actinides are the primary, long-lived isotopes that make used reactor fuel radioactive for thousands of years. A major benefit of reprocessing is to reduce the actinide content in the final waste by transmuting (in advanced reactor fuel) the long-lived actinide isotopes. While reprocessing concentrates fission products in the final waste, it shortens the radioactive lifetime of the waste substantially by removing the long-lived actinide isotopes from the mix.

The following graphic illustrates how used nuclear fuel is reprocessed to separate the material into intermediate level waste (fuel rod cladding, etc.), high level waste (fission products), and usable uranium and plutonium streams.



Liquid high-level wastes are mixed with glass-forming materials and melted. The molten glass is then poured into robust stainless-steel canisters, as shown in the graphic below, which are then sealed by welding.

The borosilicate glass block shown in the graphic contains material that is chemically identical to high-level waste from nuclear fuel reprocessing. A block this size would contain the total high-level waste arising from nuclear electricity generation for one person throughout a normal human lifetime.



Another meaningful illustration is the amount of nuclear material required to generate the electricity needs for one person's lifetime and the resulting amount of reprocessed nuclear waste requiring disposal as shown below.

Nuclear material required per person per lifetime: 1 golf ball

Volume of waste per person generated for their lifetime. These fission products remain radioactive for only 300 years.

The reprocessing debate has been predominantly a U.S. phenomenon. As mentioned above, the nuclear proliferation issue is the primary argument used to oppose the reprocessing of used nuclear fuel; that is, that recovered plutonium can be used to manufacture nuclear weapons. However, France, the United Kingdom, Russia, and India have all been reprocessing used nuclear fuel for more than 40 years. These countries don't have the nuclear proliferation concern that has prevented used nuclear fuel reprocessing in the U.S. because, as was stated in the opening paragraph, the insurmountable problem in the U.S. is politics.